Method For Reducing Line Edge Roughn ss Of Photoresist

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to method for reducing line edge roughness of photoresist, and particularly relates to method for improving precision of pattern of photoresist without changing photoresist material or changing both develop process and bake process.

2. Description of the Prior Art

For semiconductor fabrication, photoresist is an indispensable part for transferring pattern of mask into semiconductor substrate. Because pattern of photoresist essential is pattern of semiconductor substrate, how to ensure pattern of photoresist is equal to pattern of mask is an important key for whether pattern is accurately transferred.

Because practical semiconductor fabrication is limited by numerous factor, such as available materials of both photoresist and developer, unavoidable errors during both developing process and priming process, standing wave phenomena, and non-uniform distribution of polymers which are composition of photoresist. It is

often-seen that some trenches are existent in formed photoresist which is patterned. Owing to location and number of trenches are random distributed, disadvantages such as non-smooth surface and line width variation are occurred and usually is called as line edge roughness. Fig. 1A and Fig. 1B illustrate ideal shape of patterned photoresist, and both Fig. 1C and Fig. 1D qualitatively show real shape of patterned photoresist while line edge roughness is happened. Herein, all figures are not illustrated in according to practical scale for emphasizing possible variation, photoresist is formed on semiconductor substrate 10, shape of photoresist 11 could be any shape, and both location and shape of trenches 12 are random distributed.

Obviously, because shape of photoresist is changed by line width variation and non-smooth surface, critical dimension of pattern of photoresist would be increased and sequentially formed pattern on semiconductor substrate would be in disagreement with the actual shape. Thus, conventional semiconductor fabrication usually repairs patterned photoresist to reduce, even eliminate, line edge roughness of photoresist before pattern of patterned photoresist is transferred into semiconductor substrate.

Conventional semiconductor fabrications reduce line edge roughness of photoresist by modifying temperature and/or period of soft bale process, hard bake process, and/or post exposure bake process. However, because standing wave phenomena is unavoidable while photoresist is exposed by light and improvement is limited by available material of photoresist, conventional semiconductor fabrication could not effectively reduce, or even eliminate, line edge roughness of patterned photoresist.

As a summary, because conventional semiconductor fabrication could not prevent defects of line edge roughness, but effects of line edge roughness are more and more serious while critical dimension of semiconductor device being continuously shrink, it is desired to develop a new method for reducing line edge roughness of photoresist.

SUMMARY OF THE INVENTION

One main object of this invention is to effectively reduce line edge roughness of photoresist.

Another main object of this invention is to improve precision of pattern of photoresist without changing photoresist material or changing both develop process and bake process.

Still one main object of this invention is to effectively reduce line edge roughness by filling, to accomplish good control ability for control line width of photoresist.

This present invnetion provides a method of reducing line edge roughness of photoresist. Initially, provide a photoresist which at least has a trench and is located on substrate, and then fill these trenches so let that trenches are totally filled by an additional material. Next, remove part of additional material which is located on photoresist and substrate. Finally, treat additional material so let that adhesion between additional material and photoresist is enhanced after additional material is treated.

Because trenches on photoresist are filled by additional material, real pattern of photoresist could be equal to the ideal pattern, and then precession of patterned photoresist is enhanced.

Furthermore, this embodiment could be further modified as follows: omit step of removing part of additional material while only trenches are filled by additional material; and omit step of treating additional material while adhesion between additional material and photoresist is good.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation and many of the attendant advantages will be readily obtained and better understood by reference to the following detailed description and accompanying drawings.

Fig. 1A to Fig. 1B are qualitative illustration about ideal shape of photoresist;

Fig. 1C to Fig. 1D are qualitative illustration about practical shape of photoresist;

Fig. 2A through Fig.2D are cross-sectional illustrations of one preferred embodiment of this present invention; and

Fig. 3A through Fig. 3C are basic flow-chart of another preferred embodiment of this present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Because choice of photoresist material, baking time and baking temperature are strongly related to whole process for transferring pattern from mask into photoresist, none of them could be decided only in accordance with requirement for preventing line edge roughness. Thus, this present invention reduces line edge roughness of photoresist from another approach: First, still use conventional semiconductor fabrication to form photoresist pattern which has line edge roughness such as trenches, non-smooth surface, and line width variation. Then, after pattern is transformed into photoresist, fills trenches (include holes) in photoresist by an additional material, so let non-smooth surface and line width variation are reduced or even eliminated. Finally, uses both photoresist and additional material as a mask to transfer pattern into semiconductor substrate.

In short, conventional semiconductor fabrication usually directly uses photoresist as the mask used by etch process and implant process, and then photoresist which is deformed by line edge roughness reasonably could not accurately transform pattern of mask into semiconductor substrate. In contrast, thus present invnetion repair deformed photoresist by filling trenches with additional material, and then use both photoresist and additional material as the mask used by etch process and implant process. Because trenches are filled by additional material, pattern transformed into semiconductor substrate is essentially similar with desired pattern, except photoresist is too deformed, too wide or too curved to be repaired by filling additional material, or pattern of photoresist is significantly different from pattern

of mask.

One preferred embodiment of this invnetion is a method for reducing line edge roughness, at least includes following steps.

As shown in Fig. 2A and Fig. 2B, provide photoresist 21 which is located on substrate 20 and at least has one trench 22. Herein, trenches 22 could be located on sidewall of photoresist 21 or be located on top of photoresist 21. Further, particularly emphasized, trenches 22 are unavoidable defects during formation of photoresist 21 and both location and shape of trenches are random distributed.

As shown in Fig. 2C and Fig. 2D, fill trenches 23 to let all trenches 22 are totally filled by additional material 23. Herein, available method for filling trenches 22 with additional material 23 at least could be spin coating, dip, or spray. Moreover, to ensure additional material 23 and photoresist 21 is effective attached to each other, additional material 23 usually are material which could be adhered to photoresist 21 by chemical reaction, such as chemical bonding, or by physical adsorption, such as capillary phenomena.

Additional material 23 usually is fluid material, such as solution and/or suspension, to ensure all trenches are totally filled by additional material 23. Moreover, additional material 23 could be thermosetting polymer, thermoplasticity polymer, and/or any material which could be reacted with hydroxyl group or proton in photoresist 21. Possible materials of additional material 23 at least include following: PMMA, POLY IMIDE, RELACS, material with a functional group of -NH groups, and material with a functional group of -OH groups. Herein,

PMMA, POLY IMIDE, and RELACS all are well-known materials of current semiconductor fabrication, for example, RELACS is a electronic materials which is produced by Clariant Inc., it's applications are not declared as what this invnetion.

However, although additional material 23 with higher fluidity is better for filling trenches, it also is possible that additional material 23 is not firmly fixed to photoresist 21, especially is not firmly fixed to photoresist 21 during sequentially etch process or implant process. Thus, as Fig. 3A shows, this present invnetion could further perform a treat process after additional material 23 is filled, to enhance adhesion between photoresist 21 and additional material 23.

As photoresist block 31 shows, provide a photoresist with at least one trench.

As fill block 32 shows, fill trenches to let trenches are totally filled by additional material.

As enhance adhesion block 33 shows, treat additional material to enhance adhesion between additional material and photoresist. Herein, available methods for treating additional material at least include one of following methods: thermal treatment, ultraviolet light curing, electrons beam curing, treatment of chemical reaction, and chemical reaction between numerous functional groups of photoresist and numerous functional groups of additional materials.

Furthermore, because it is hard to only fill addition material 23 into trenches 22 without filling additional material 23 on surface of

photoresist and/or on substrate, especially considers cost required for precisely filling process and reduction of throughput. As Fig. 3B shows, this invention could further remove any additional material 23 which locates on surface of photoresist 21 or on substrate 20 after all trenches 22 is filled, to ensure pattern formed by both additional material 23 and photoresist 21 is not deformed, at most is slightly widen.

As photoresist block 31 shows, provide a photoresist with at least one trench.

As fill block 32 shows, fill trenches to let trenches are totally filled by additional material.

As partial removal block 34 shows, remove part of additional material, where removed part of additional material is located on photoresist and substrate.

Certainly, if it is necessary, both adhesion enhance block 33 and partial removal block 34 could be used, and then basic flow-chart is shown in Fig. 3C.

As photoresist block 31 shows, provide a photoresist with at least one trench.

As fill block 32 shows, fill trenches to let trenches are totally filled by additional material.

As partial removal block 34 shows, remove part of additional

material, where removed part of additional material is located on photoresist and substrate.

As enhance adhesion block 33 shows, treat additional material to let that adhesion between additional material and photoresist is enhanced after additional material is treated. Herein, available methods for treating additional material at least include one of following methods: thermal treatment, violet light curing, electrons beam curing, treatment of chemical reaction, and chemical reaction between numerous functional groups of photoresist and numerous functional groups of additional materials.

From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for the purpose of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.